

DIRECT-CONVERSION RECEIVER SYSTEM AND METHOD, ESPECIALLY A GPS RECEIVER SYSTEM WITH HIGH PASS FILTERING

Background of the invention

The invention relates generally to direct-conversion radio receivers and to methods in direct conversion, especially for phase modulated carrier signals transmitting digital information. The invention also relates to suppression of direct current (DC) offsets generated in receivers.

In digital modulation, the modulating signal is digital, containing a bit stream of "1s" and "0s", and mixed in a modulator with a carrier signal for transmission. The basic modulation schemes are amplitude-shift keying (ASK), frequency-shift keying (FSK) and phase-shift keying (PSK). In PSK, the signals representing the states "1" and "0" have a difference in phase. In binary phase-shift keying (BPSK), the phase has two different states. In quadriphase-shift keying (QPSK) modulation, the phase has four different states. In digital modulation changes in the modulated signal waveform spread the power of the signal to a wide frequency range. The spectrum of the signal comprises usually a wide main lobe at a carrier frequency. The main lobe has smaller side lobes around it on a frequency scale. Before modulation, at a direct current (DC) or baseband, the spectrum is just one half of this and the carrier frequency represents a zero frequency (0 Hz). The lobes are separated by notches, i.e. null points situated at multiples of the data rate (including the multiple of 1), i.e. bit rate (bits per second), from the carrier frequency.

Direct-conversion receivers, i.e. zero-IF receivers are known in the art. In a zero-IF receiver (IF, Intermediate frequency) received signals are mixed with an output of a down conversion oscillator to translate the received signal to the baseband. A down conversion oscillator is a local oscillator generating a signal on the carrier frequency. The phase-modulated input signal is split into two branches and the frequency of the local oscillator is mixed with the two branches (the other one with a

90° difference in phase). The output mixed signal in a branch without any phase shift is the in-phase signal (I), and the other one having a 90° difference in phase is the quadrature signal (Q). Lowpass or complex filters are provided to remove undesired sum products caused by mixer nonlinearities from the mixing. I/Q signals are preamplified, if needed, and input to analog to digital converters (ADCs) for signal processing. A demodulated signal is calculated from the I and Q signals using a processor system (DSP, Digital signal processing). The I and Q signals also exhibit DC offsets.

In direct-conversion receivers the pure carrier signal gives rise to a DC signal at the mixer output. Other undesired signals at the mixer input give rise to mixing products, the spectrum of which is located around the DC. Other sources of DC offsets include the synchronization of a local oscillator at a carrier frequency and the DC offsets in amplifiers and other circuit elements of the receiver due to temperature, aging, crosstalk, etc. The high gain of the baseband circuitry of the receiver amplifies DC offsets to the extent that the operating range of the circuitry is exceeded. Often the DC offset is compensated using a DC nulling circuitry that measures the offset before the reception and cancels it by means of a voltage that is charged into a large capacitor. High-level transmitters, interfering the reception of a signal of a lower level transmission signal, and starting or stopping their transmission during reception of a spread spectrum device change the DC offset and thus cause disfunctionality in the receiver. The DC offset compensation should be active during the actual spread-spectrum reception, which, on the other hand, results in a more complicated compensation circuitry.

DC offset voltages have a large dynamic range when compared to a useful signal spectrum, resulting in amplifier saturation or problems with the ADC conversion. One method to block the DC offsets is to AC couple the output of the mixer with a large coupling capacitor for generating a narrow notch at a DC frequency. Large capacitors are used to facilitate the use of very low corner frequencies near the zero frequency. The portion of the modulated signal centered around the carrier frequency is also lost, wherein distortion is caused in the

demodulation, since the DC notch frequencies contain information. Large capacitors require high current drive capability consuming a lot of power and using a lot of space on printed circuit boards (PCBs).

Summary of the Invention

- 5 An object of the present invention is to provide a method in a direct-conversion receiver for processing received radio signals that are modulated and centered at a carrier frequency.

- 10 Another object of the present invention is to provide a direct-conversion receiver for processing modulated radio signals that are centered at a carrier frequency.

- 15 Another object of the present invention is to provide a GPS direct conversion receiver for processing phase-modulated radio signals that are centered at a carrier frequency for receiving digital information.

- 20 Another object of the present invention is to provide a method for processing modulated radio signals that are centered at a carrier frequency in a direct conversion receiver.

- 25 With the invention, considerable advantages are achieved. A portion of the modulated signal centered around the carrier frequency is preserved and information is not lost. The use of other than large capacitors is facilitated since a notch generated by the AC coupling is situated at notches or null points of the signal spectrum. Consequently, lost modulation energy due AC coupling is considerably lower compared to the case when the AC coupling is at the center of a lobe of the spectrum.

- 30 In accordance with the present invention, a local oscillator used exhibits a frequency offset from the carrier frequency of the received signal. In prior art receivers, complicated control circuits were used to tune the frequency of the local oscillator as precisely as possible to the carrier frequency. In the present invention, a direct conversion receiver
35 includes the AC coupling and the offset frequency is such that the

frequency spectrum of the modulated signal is moved accordingly to align the DC notch at a spectrum notch, i.e. the frequency of the local oscillator equals with or is about a null point of the modulated signal spectrum, fluctuations and necessary, small differences permitting.

- 5 Therefore, requirements for the AC coupling are easier to fulfill, the amount of lost energy and information is minimized and distortion of the modulated signal is reduced.

10 One advantage of the present invention is that high pass filters (for example a first order filter comprising a capacitor in series and corresponding to the AC coupling) in I and Q branches of the receiver are filtering out energy from the offsets which do not contain any significant or any amount of modulation power. The size of the capacitor is determined by a desired frequency crossover point (amount of power reduction vs. null frequency). The higher the value of the capacitor, the lower the high pass frequency will be. Reduction of power increases at frequencies lower than a filter corner frequency which equals to or is slightly higher than the null frequency.

15 20 In particular, the present invention is used in spread spectrum systems such as GPS (Global Positioning System) using CDMA techniques. CDMA (Code Division Multiple Access) is a known method of frequency reuse whereby many transmitters use the same frequency but each has a unique code. The transmitted signal is spread over a frequency band much wider than the minimum bandwidth needed to transmit the information being sent. In GPS this is done by modulating with a pseudo random code. In GPS digital communication the transition time for individual bits is called chip rate, which for the GPS carrier is 1.023 MHz.

25 30 In the present invention, the local oscillator offset is set to multiples of 1.023 MHz (first null at 1.023 Hz, second null at 2.046, etc.) equalling to the spectral nulls of a biphase-modulated signal.

Brief Description of the Drawings

In the following, the present invention will be described in more detail with reference to the appended drawings, in which

5 Fig. 1 shows an example of modulated GPS signal spectrum shown on baseband frequency, and

Fig. 2 shows a block diagram of a direct conversion receiver in accordance with the present invention.

10 Detailed Description of Embodiments

Fig. 1 shows the most significant part of a modulated GPS signal spectrum at baseband frequency with a main lobe and side lobes, which all form the applicable sideband on both sides of the carrier frequency. The horizontal frequency scale is normalized to correspond to the chip rate (inverse of the bit duration time) in order to show the signal going through null points periodically and the spectral notches (i.e. null points) at the multiples of the chip rate. The difference between the notches and the normalized zero frequency correspond to the frequency offset of the local oscillator (the offset frequency equalling to or being about the local oscillator frequency minus the carrier signal frequency). The DC notch caused by the AC coupling is also shown in broken line. The vertical power density scale in decibel (dB) is normalized to correspond to the main lobe. In the present invention, due to the offset frequency, the signal spectrum is moved right and a notch to the left from the main lobe is aligned with the center frequency. The receiver comprises bandpass or complex filtering in I and Q branches for further suppression of undesired mixing products and adjacent channels. The complex filtering has nonsymmetrical response around zero frequency and they effect better noise bandwidth.

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Fig. 2 shows the essential parts of the direct conversion receiver (i.e. zero-IF receiver) 1 to the extent necessary for the understanding of the invention. A more detailed selection of components and subsystems based on this description is clear to a person skilled in the art. A means

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for receiving and splitting radio signals comprise, for example, an antenna 2, an amplifier 3, and a divider 4). The incoming radio signal (RF, Radio frequency), which is received using the antenna 2 and usually preamplified in the amplifier 3, is split into a first component and a second component (usually using the signal divider 4). The first component is fed to a first mixer means 5 in which the first signal part is mixed with a signal present at first output 6 of a local oscillator 7. As a result of this, an in-phase signal I is generated at the mixer 5 output. Undesired mixing products and also DC offsets are separated off in a filtering means formed by an AC coupling 8 and a first filter 9, for example. The filtered signal is fed to a signal amplifier 10 and after that to a first ADC-converter 11. The signal is further fed to a processor system 12, containing other circuit assemblies and blocks, for demodulation and further processing. Usually the oscillator 7 is regulated, for example to select the offset frequency, by the processor system 12.

The second component is fed to a second mixer means 13 in which the second signal part is mixed with a signal present at a second output 14 of the local oscillator 7. The signal at the second output 14 is phase shifted 90° in relation to the signal at the first output 6. As a result of this, the quadrature signal Q is generated at the output of the mixer 13. Undesired mixing products and also DC offsets are separated off in an AC coupling 15 and a second filter 16. The filtered signal is fed to a signal amplifier 17 and after that to a second AD-converter 18. The signal is further fed to a processor system 12.

The direct conversion receiver forms a part of a receiver system dedicated, for example and specifically, to the GPS reception and information processing. Further components of the GPS receiver are chosen according to desired specifications in a way known as such to a person skilled in the art.

The invention is not limited to the above-described examples or to the drawings showing examples of one embodiment, but can be varied within the scope of the appended claims.